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Marginal adaptation of ceramic and composite inlays in minimally invasive mod cavities

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Abstract: OBJECTIVES: This study aims to evaluate the effect of a minimally invasive mesial-occlusal-distal (mod) preparation on the marginal adaptation of ceramic and composite inlays with the aim of saving sound dental substance. MATERIALS AND METHODS: Class II mod cavities were prepared in 50 extracted human molars and randomly allocated to five groups (n = 10). In all groups, the mesial-proximal box margins were located in the dentin, 1 mm below the cementoenamel junction (CEJ), while the distal box margins were 1 mm above the CEJ. In groups A and B, conventional standard preparations with a divergent angle of = 6° were prepared. In groups C, D, and E, minimally invasive standard preparations with a convergent angle of = 10° were prepared. In groups A and D, composite inlays and, in groups B and C, ceramic inlays were fabricated (chairside economical restoration of esthetic ceramics (CEREC)) and adhesively inserted. In group E, a direct composite filling using the incremental technique was placed. Replicas were taken before and after thermomechanical loading (1,200,000 cycles, 50/5 °C, max. load 49 N). Marginal integrity (tooth-luting composite, luting composite-inlay) was evaluated by scanning electron microscopy (×200). The percentage of continuous margins in the different locations was compared between and within groups before and after cycling, using ANOVA and Scheffé post hoc test. RESULTS: After the thermomechanical loading, no significant differences were observed between the different groups with respect to the interface of luting composite-inlay. At the interface of tooth-luting composite for preparations involving the dentin, groups A and B behaved significantly better compared to the control group E, which in turn were not different to groups C and D. CONCLUSION: Composite and ceramic inlays inserted in minimally invasive prepared mod cavities result in margins not different from those of inlays placed in conventional mod preparations. Direct composite filling margins, however, were inferior to those attained by conventional indirect restorations. CLINICAL RELEVANCE: Minimally invasive preparations for mod inlays with undercuts show marginal adaptation equal to that of conventional inlay preparation design.

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Marginal adaptation of ceramic and composite inlays in minimally-invasive mod-cavities.

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Declaration of interests:

The authors declare they have no conflicts of interest.

Abstract

Objectives To evaluate the effect of a minimally-invasive mod-preparation on the marginal adaptation of ceramic and composite inlays with the aim of saving sound dental substance.

Materials and Methods Class II mod-cavities were prepared in 50 extracted human molars and randomly allocated to five groups (n=10). In all groups, the mesial-proximal-box-margins were located in dentin, 1 mm below the cementoenamel junction (CEJ), while the distal-box-margins were 1 mm above the CEJ. In group A and B, conventional standard preparations with a *divergent* angle of α = 6° were prepared. In Group C, D and E minimally invasive standard preparations with a *convergent* angle of α = 10° were prepared. In groups A and D composite inlays and in groups B and C ceramic inlays were fabricated (CEREC) and adhesively inserted. In Group E, a direct composite filling using the incremental technique was placed. Replicas were taken before and after thermomechanical loading (1,200,000 cycles, 50/5°C, max. load 49 N). Marginal integrity (tooth-luting composite, luting composite-inlay) was evaluated with scanning electron microscopy (200x). The percentage of continuous margins in the different locations were compared between and within groups before and after cycling, using ANOVA and Scheffé post-hoc test.

Results After thermomechanical loading, no significant differences were observed between the different groups with respect to the interface luting composite-inlay. At the interface tooth-luting composite for preparations involving dentin, groups A and B behaved significantly better compared to the control group E, which in turn were not different to groups C and D.

Conclusion Composite and ceramic inlays inserted in minimally invasive prepared mod-cavities result in margins not different from those of inlays placed in conventional mod-preparations. Direct composite filling margins however, were inferior to those attained with conventional indirect restorations.

Clinical relevance Minimally-invasive preparations for mod-inlays with undercuts show marginal adaptation equal to conventional inlay preparation design.

Introduction

The present study evaluated the effect of minimally-invasive mod-preparations with undercuts on the marginal adaptation of composite and ceramic inlays, with the aim of saving healthy dental substance.

Since introduction of adhesive technology in dentistry [1], Black`s guideline of extension for prevention“ has changed to “prevention instead of extension” [2]. Adhesive systems, allow for new cavity designs to be used with composite materials [3], as they no longer require a special retention form as do amalgam or metal inlay restorations. Attention can now be focused on maximal preservation of dental hard tissue, and a minimally-invasive design should be selected for the given situation. This is especially advantageous in cases of lost or failed restorations. Removal of sound dental hard tissue can be avoided in these situations by using a minimally-invasive preparation procedure, Thereby increasing the longevity of the tooth.

Resin composites have undergone enormous development since their first usage in dentistry in the 1950s by Buonocore [1, 4]. With improved wear resistance, strength, esthetics and reduced water absorption in comparison to previous materials, composite fillings are increasingly being placed in posterior, as well as anterior areas of the mouth [5]. Nevertheless, polymerization shrinkage [6-8] and microleakage [9] of resin-based restorative materials remain unsolved problems in clinical dentistry. Due to shrinkage, especially in direct class II adhesive restorations, incremental methods [10-14], the use of ceramic inserts [15] or the application of a base [12, 16] have been suggested to counteract this polymerization shrinkage and to reduce stress development within the tooth-restoration system. Polymerization shrinkage is influenced by different parameters [17], such as material properties [18], configuration factor [19, 20], cavity size, presence or absence of enamel at cavity margins and the dentin quality, morphology and location [21, 22]. Especially in larger cavity sizes, the indirect restoration technique could help reducing the polymerization contraction, which is restricted to the thin composite cement layer [23].

As an indirect technique, CAD/CAM restorations such as the Cerec restoration process, come into consideration [24], showing a survival rate comparable to casted gold restorations [4, 25-27]. To date, special industrially fabricated ceramic blocks are used with the Cerec System. But more recently, composite blocks [28] have demonstrated great potential, limiting the risk of cuspal fracture below CEJ when compared to porcelain onlays [29, 30].

Using composite resin blocks in CAD/CAM procedures may present an additional advantage in terms of milling time and conservation of tooth structure. Physical properties allow milling in thin layers [31], may be advantageous in restoring primary teeth and also for substitution of, for example, amalgam fillings or indirect gold restorations. In addition, the prefabricated blocks are industrially fabricated and highly homogeneous, which should improve the mechanical properties and therefore the performance of the restoration over time compared to direct filling procedures [28].

To date, various preparation guidelines exist for inlay restorations [24, 32-34]. Especially for ceramic inlays, a cavity angle of approximately 6 to 10 degrees is recommended. Therefore, sound tooth structure might be sacrificed to achieve a conventional divergent geometrical design. Especially the more coronal located parts of the cavity have to be removed. So while, an undermined preparation design would save sound tissue, it would also lead to a broader luting margin cervically.

Due to of the above mentioned considerations, this study was designed to evaluate the effect of a minimally invasive mod-preparation design with undercuts on the marginal adaptation of direct composite fillings, composite inlays and ceramic inlays, and compare them to conventional divergent preparations. The null hypothesis tested in this study is that there will be no difference in marginal adaptation between the different preparation designs and materials used.

Materials and methods

Sample preparation

Fifty intact, caries-free human molars with completed root formation, which were stored in 0.1% thymol solution between extraction and use, were selected for this in-vitro test. Extracted teeth were collected as anonymous by-products of regular therapy. According to that, our Medical Ethical Board stated that the performed research was not conducted under the regulations of the "Act on Medical Research Involving Human Subjects" (METc 2009.305). Therefore a written informed consent was not required. Before treatment, patients were informed about general research purposes and gave verbal agreement, which was not documented to keep the procedures anonymously. After cleaning, the molars were randomly assigned to five experimental groups (n = 10). All teeth were prepared for the simulation of pulpal pressure according to a protocol described by Krejci et al. [35]. The roots of the teeth were centrally mounted to roughened specimen carriers (SEM mounts, Baltec AG, Balzers, Liechtenstein) with superglue (Renfert Sekundenkleber Nr 1733, Dentex AG, Zürich) and embedded in auto-polymerizing resin (Paladur, Heraeus Kulzer, Wehrheim, Germany). Intrapulpal pressure was maintained at 25 mmHg throughout the whole experiment, i.e. during cavity preparation, restoration placement, finishing and thermomechanical loading (TML). For the standard preparations a drilling machine (Proxxon BFW 40/E, Niersbach, Germany) with specially developed holder, adjustable in all three dimensions, was used. In Group A and B, standardized non-bevelled mesial-occlusal-distal (mod) class II-cavities with a divergent angle of 6° were prepared using 46 μm diamond burs (ISO 80610472514040, Busch, Engelskirchen, Germany) under water-cooling. For the minimally-invasive convergent preparations, a special bur was turned of carbide metal and coated with 46 μm diamonds (Intensiv SA, Grancia, Switzerland). All diamond burs were 4 mm diameter at the working end. Firstly, the tooth was adjusted with its occluso-apical axis perpendicular to the bottom. Based on the deepest point of the fissure, the bur was positioned 2.5 mm deeper at the proximal side and the occlusal box was ground. Thereafter, the mesial box was ground 1 mm below the cementoenamel junction (CEJ) (Fig. 1), and the distal box 1 mm above CEJ (Fig. 2). Afterwards, all inner line angles of the cavities were smoothed under 12x magnification (Stemi 2000, Carl Zeiss; Feldbach, Switzerland) using a 25 μm diamond bur (Intensiv SA) and a hand piece under water-cooling. Additionally, for the composite group E, the proximal margins were bevelled using an ultrasonic device [36] (miniPiezon®, EMS, Nyon, Switzerland). Only one optical impression of each preparation in groups A, B, C and D was performed and virtual mod-inlays were constructed using the Cerec AC Bluecam (Sirona, Bensheim, Germany) with the software version V3.80. In group B and C, inlays were milled from prefabricated leucite-reinforced glass-ceramic blocs (IPS.Empress.CAD, LTC2, Ivoclar Vivadent, Schaan, Liechtenstein) and in Group A and D from industrial produced composite blocs (Paradigm MZ100, B3, 3M Espe, St. Paul, MN, USA) with a Cerec milling machine (MCXL, Sirona). The fit of the ceramic inlays into the respective cavity was controlled with a low viscosity polyvinysiloxane (Fit Checker, GC, Tokyo, Japan) and stereomicroscope (Stemi 2000, Carl Zeiss) at a 12x magnification. For cementation, all cavities were totally etched (enamel: 30 s; dentin: 15 s) with 35% phosphoric acid (Ultraetch, Ultradent, South Jordan, UT, USA) and rinsed with water for 40 s and followed by drying with oil-free air. Then, the adhesive system (Syntac Primer, Syntac Adhesive, Heliobond, Ivoclar Vivadent) was applied according to the manufacturer's instructions. The bonding was light-cured for 40 s (Mode: HIP, 1200 mW/cm^2, Bluephase, Ivoclar Vivadent). The surface conditioning of the milled composite restorations included airborne-particle abrasion with 50 μm aluminium oxide followed by cleaning using 35% phosphoric acid (Ultraetch, Ultradent) with a gentle brushing motion for 1 minute, rinsing with water for 20 s and subsequent silanization (Monobond-S, Ivoclar Vivadent) for 60 s. The internal surface of the ceramic inlays were first cleaned with alcohol and then etched for 60 s with 5% hydrofluoric acid (Vita Ceramics Etch, Vita Zahnfabrik, Bad Säckingen, Germany). After 60 s rinsing and drying, a coupling silane (Monobond-S, Ivoclar Vivadent) was applied and left undisturbed for 60 s followed by air-drying. Afterwards, a thin layer of bonding resin (Heliobond, Ivoclar Viviadent) was applied onto the inner surface of the restorations. The inlays were first manually and then ultrasonically seated with a nanohybrid composite (Filtek Supreme XT, XWB, 3M Espe), which was preheated for 5 min to 37°C (Calset, Addent, Danbury, CT, USA). With a dental probe, excess material was carefully removed and finally all margins were covered with glycerin gel (Airblock, Dentsply DeTrey GmbH, Konstanz, Germany) to avoid oxygen inhibited layer formation. Each side (mesio- and disto-buccal / mesio- and disto-lingual / mesio- and disto-occlusal) was light-cured for 40 s with a polymerisation light (Mode: HIP, 1200 mW/cm^2, Bluephase, Ivoclar Vivadent) as proposed by Lutz et al. [12]. For controlling the light output of the LED device, a radiometer (Optilux Radiometer, SDS Kerr; Orange, CA, USA) was used to prove that the power was always above 1000 mW/cm^2. In Group E an incremental direct filling technique was used. First, the proximal boxes were restored with three increments for each box. Then one buccal and one lingual increment of the occlusal side was placed. Each increment was light cured for 40 s using the same polymerisation light. All restorations were finished with 15 μm fine diamond burs (Intensiv SA) and polishing discs (Soflex, 3M-ESPE, Rüschlikon, Switzerland) under continuous water cooling and descending roughness. The polishing procedure was observed under a stereomicroscope (Stemi 2000, Carl Zeiss) at 12x magnification.

Thermomechanical loading (TML)

For TML, mesio-palatinal cusps of human maxillary caries-free molars were separated, and embedded in amalgam (Dispersalloy, Dentsply DeTrey GmbH) and fixed onto a carrier [37]. These samples were later used as antagonists. The antagonists were stored in water during the whole experiment to avoid desiccation [38]. Then, they were mounted together with the specimen in the sample chambers of the TML machine. The occlusal contacts were marked with articulating paper to ensure that the loading area was in the center of the occlusal inlay surface, not contacting the margins of the preparations. All restored teeth were loaded with repeated thermal and mechanical stresses in a computer-controlled masticator (CoCoM 2, PPK, Zürich, Switzerland) for 1.2 Mio cycles with 49 N at 1.7 Hz. [37-39]. Thermal cycling was carried out during the loading cycles by flushing water with temperature changing 6000 times from 5 to 50°C [40].

Quantitative marginal SEM analysis

Before (initial) and after (terminal) TML, impressions of the mesial and distal boxes were taken using an A-polyvinylsiloxane (President light body, Coltène). The impressions were poured out with epoxy resin (Stycast 1266, Emerson & Cuming, Westerlo, Belgium) and glued (Superglue 1733, Renfert, Hilzing, Germany) onto a customized sample carrier and sputter-coated with gold (Sputer SCD 030, Balzers Union, Balzers, Liechtenstein). All specimens were examined for quantitative marginal analysis with a scanning electron microscope (Amray 1810/T, Amray; Bedford, MA, USA) at 10 kV and 200x magnification by one examiner, who was blinded with respect to the group assignment of the specimens. Two different interfaces were evaluated for marginal integrity at the proximal cavity walls. First, the interface between tooth and luting composite (tooth-luting composite) and second, the interface between luting composite and inlay (luting composite-inlay). All specimens were examined for “continuous” margins (no gap, no interruption of continuity) and imperfect “non-continuous” margins (gap due to adhesive or cohesive failure; restoration or enamel fractures related to restoration margins).

For the preparation boxes below CEJ, the percentage of continuous margins are separated in margins in enamel (group Ae–Ee) and margins in dentin (group Ad–Ed). For the preparation boxes located only in enamel (A^+-E^+), total values of the percentage of continuous margins are presented.

Statistical analysis

Marginal quality was expressed as a percentage of continuous margins over the margin length (100% = no discontinuous aspects) both before (initial) and after (terminal) TML. Statistical analysis was performed with SPSS (Version 16.0, SPSS Inc., Chicago, IL, USA). Differences between groups were tested using analysis of variance (ANOVA) and Scheffé post-hoc test ($p < 0.05$). Additionally, for each treatment group separately the Wilcoxon Signed Rank test were used to investigate the difference between the initial and the terminal value of the continuous margin ($p < 0.05$).

Results

Interface tooth–luting composite of preparations below CEJ for margins only in enamel (Ae–Ee):

The percentages of continuous margins in enamel are given in Fig. 3.Initial percentages of continuous margin of groups Ae (91.2 ± 9.4%), Be (89.9 ± 11.5%), Ce (91.9 ± 6.1) and Ee (78.4 ± 15.5%) were not statistically significantly different when compared with each other ($p > 0.05$, respectively). Furthermore, no significant difference in the percentages of continuous margin of groups Ae, Be, Ce and De (91.9 ± 4.8%) ($p > 0.05$, respectively) was observed. The percentage of continuous margin in group Ee was significantly lower compared to that of group De ($p < 0.05$).

TML led to a significantly reduction of continuous margin in groups Ae, Ce, De and Ee, while in group Be no significantly lower percentage of continuous margin was observed.

After TML, no significant difference in the marginal adaptation was observed ($p = 0.067$) between any of the groups.

Interface tooth–luting composite of preparations below CEJ with margins for margins only in dentin (Ad–Ed):

The percentages of continuous margins in dentin are given in Fig. 4. The percentage of continuous margin in group Ed (91.9 ± 4.8%) was significantly lower compared with groups Ad (91.5 ± 12.4%), Bd (85.0 ± 7.6%), Cd (87.8 ± 9.8%) and Dd (95.6 ± 1.8%) ($p < 0.05$, respectively). Within the groups Ad, Bd, Cd and Dd no significant difference in the percentage of continuous margin was found.

TML led to a significantly lower percentage of continuous margin for groups Ad, Cd and Dd when compared with the respective initial values ($p < 0.05$, respectively). For the remaining groups no significant lower percentage of continuous margin was observed.

After TML no significant difference in the percentage of continuous margin of groups Ad (79.8 ± 27.0%), Bd (79.9 ± 16.1%), Cd (77.7 ± 11.8%) and Dd (72.1 ± 16.7%) was found.

Group Ed (49.9 ± 27.0%) showed a significantly lower percentage of continuous margin when compared with groups Ad and Bd ($p < 0.05$, respectively).

Interface tooth–luting composite of preparations above CEJ for margins in enamel (A^+-E^+):

The percentages of continuous margins in enamel are given in Fig. 5. Initially, the percentage of continuous margin in group E^+ (82.4 ± 8.6%) was significantly lower when compared with the groups A^+ (94.5 ± 5.8%), B^+ (94.2 ± 6.0%) and D^+ (94.0 ± 4.0%). Groups A^+, B^+, C^+ and D^+ were not significantly different when compared with each other ($p > 0.05$, respectively). For all groups, except group C^+, the TML led to a significant reduction of the percentages of continuous margin ($p < 0.05$, respectively).

After TML the percentage of continuous margin of groups A^+ (73.8 ± 17.2%), B^+ (85.6 ± 8.8%), C^+ (89.9 ± 6.0%) and D^+ (79.5 ± 16.8%) were not significantly different.

In group E^+ (69.8 ± 15.3%) a significantly lower percentage of continuous margin was observed when compared with group C^+.

Interface luting composite–inlay:

Due to the direct composite filling treatment in group E, no evaluation was performed for this interface. For all other treatment groups, no statistically significant influence on the percentage of continuous margins was observed at terminal evaluation ($p > 0.05$, respectively).

Discussion

The purpose of this study was to evaluate the effect of a minimally-invasive mod-preparation on the marginal adaptation of composite and ceramic inlays, with the aim of saving sound tooth structure. In this in-vitro-study, all specimens were evaluated by SEM after TML. To simulate the clinical environment, an especially developed well-proven chewing machine with additional artificial aging through thermocycling was used [37, 41, 42]. The advantage of this method is a reproducible standardized stress for all specimens. In addition, intrapulpal pressure was used to simulate physiological conditions [43]. Therefore, it could be assumed that the results of this study might have a certain clinical relevance. However, TML is influenced by a number of factors, including applied force, force profile, contact time, sliding movement and clearance of worn material. These factors are not controlled in every phase of the simulation [44].

It must be considered in our study, that only one brand of composite for luting and direct restoration was used. Generally, luting composites, even of similar composition, can differ considerably in their chemical and physical characteristics [45, 46], and are hence affected in different ways by light polymerization [47]. In addition the use of a highly filled and viscous composite for luting the restoration has obvious advantages since it does not flow over all surfaces and may be easily removed with a probe, spatula or floss. This is a critical step in the cementation process and for removing the remaining overhangs we recommend for the clinical procedure to use a spatula with gently sliding motions always parallel to the surface starting from the inner proximal cervical parts to the lateral more occlusal box margins. For easier handling and better cervical marginal adaptation [48], a nanofilled luting composite was preheated to 37°C prior to insertion, to reduce the viscosity [49]. The temperature chosen in this study was similar to that of the oral cavity. With higher temperatures ($T > 37°C$) increased cuspal movement has been observed [50], leading to a greater challenge on the bond to tooth interface. Additionally, higher final monomer conversion values can be achieved with pre-heated composite, thereby reducing the amount of unreacted monomer, which may potentially leach into oral cavity [51].

Before TML, a good marginal fit was achieved by all indirect restorations for the tooth-composite margin. This is in accordance with the literature [52, 53]. After TML, a reduction of the percentage of continuous margin could be observed for all groups. This finding demonstrates that the marginal adaptation of adhesively inserted restorations disintegrates through TML [42, 54-56].

In the groups (Ae–Ee) with preparations additionally in dentin, no significant differences ($p < 0.05$) between all groups for margins located in enamel could be detected after TML. In the literature, larger proportions of enamel micro-fractures were observed in in-vitro mechanical loading tests conducted on cavities with a butt margin design [55, 57-59]. The parallel orientation of enamel prisms in the axial wall, in combination with the weakened region of non-bevelled enamel after phosphoric acid conditioning could be an explanation for these findings and may led to a reduction of marginal adaptation after TML.

For the groups with preparations extending into dentin, the conventionally prepared cavity groups Ad and Bd showed significantly higher values ($p < 0.05$) at the tooth-luting composite margin when compared with the direct composite group Ed, but not significantly in comparison with the minimally-invasive preparations with ceramic (group Cd) or composite inlays (group Dd). Therefore the null hypothesis must be rejected. The lower values of continuous margins in the direct composite fillings may be attributed to polymerization shrinkage, which remains an unavoidable problem and may compromise the integrity and longevity of posterior restorations [60], particularly those with margins in dentin [61]. Additionally, the potential for marginal gaps and microleakage increases with cavosurface margins in dentin due to the biological variability of this tissue [62]. To minimize the adverse effects of polymerization shrinkage, an incremental placement technique was performed [43, 63].

Cerec 3 restorations exhibit a luting space, which is less than 100 μm [26, 64]. This might have led to a reduction of the polymerization shrinkage, especially in the groups with a conventional preparation including angles of approximately $\alpha = 6°$. However, a large cementing space partially compensates for the polymerization stresses, allowing the tooth structure and the restoration to undergo micro movements during the luting procedure [65-67]. However, these observations are in contrast to the findings of Manhart et al. [68], where almost perfect marginal adaptation in class-II mod enamel cavities were reported after loading when direct composite, composite inlays, and ceramic inlays were used as filling or restoration materials. In the study by Manhart [68] different loading conditions (only 50,000 cycles against 1.2 million in the present study) as well as no dentinal fluid simulation were used which may influence the results. In addition, Manhart considered other cavity configurations, which may play an important role in the absorption and distribution of mechanical stresses.

All composite and ceramic inlay groups (A^+-D^+) showed similar values of continuous margin for preparations above CEJ ($p > 0.05$) at the tooth-luting composite margin. In group C^+ significantly higher percentages of continuous margin were observed when compared with the direct filling group E^+. These results are in agreement with those of recent investigations [69-71].

The lower Youngs modulus of composites might be responsible for this observation [72]. In Case of Paradigm MZ the results could be transferable to Lava™ Ultimate (3M Espe, Seefeld, Germany) due to the similar mechanical properties like Youngs modulus. Ceramic restorations provide a higher modulus of elasticity that reduces deformation of the tooth and therefore deformations at the margin of the restoration [73].

In the present study, only one optical impression was performed for the indirect inlay restorations. This strategy was chosen to take into account that the fabrication of several optical impressions of the preparation with the current software (V3.80 and SW4.0) would lead to undercuts in the afterwards matched virtual model. The existence of these undercuts would result in fabrication of inlays which could not be inserted into the cavity. For undercuts inside the preparation, however, the software automatically blocks out the undercuts with respect to the selected insertion axis. Due to these facts, only one optical impression was performed. With this method, the software automatically interpolates the missing data of the undercuts referring to the axis of the optical impression, resulting in a calculated virtual model without undercuts. Accordingly, a special software mode for undercuts with the option of multiple optical impressions would be desirable. Additionally, less loss of dental hard tissue, especially in the occlusal and proximal parts offers the advantage that more information can be extracted for the biogeneric software [74, 75] and, as a side-effect, a better occlusal morphology of the restoration may be designed.

Considering traditional principles of fixed prosthodontics, full crown coverage is often recommended to strengthen the remaining tooth substance. When compared to bonded restorations, traditional full-crown coverage restorations, however, require a sacrifice of more dental hard tissue [76, 77]. Additionally, full crown reconstructions are more frequently associated with gingival inflammation and secondary caries [78]. With the method described, replacement of cusps is not always necessary and preservation of sound dental hard tissue is possible. Especially with chairside CAD/CAM methods, an additional advantage is the availability of an optimal dentinal substrate, allowing adhesion to freshly cut dentin without contamination by temporary cements [79-81].

Conclusion

Within the limits and considerations of this in-vitro study, the minimally-invasive preparation approach with proximal undercuts for composite and ceramic inlays showed no differences concerning marginal adaptation when compared with the conventional divergent preparations and should be considered as an alternative in clinical practice.

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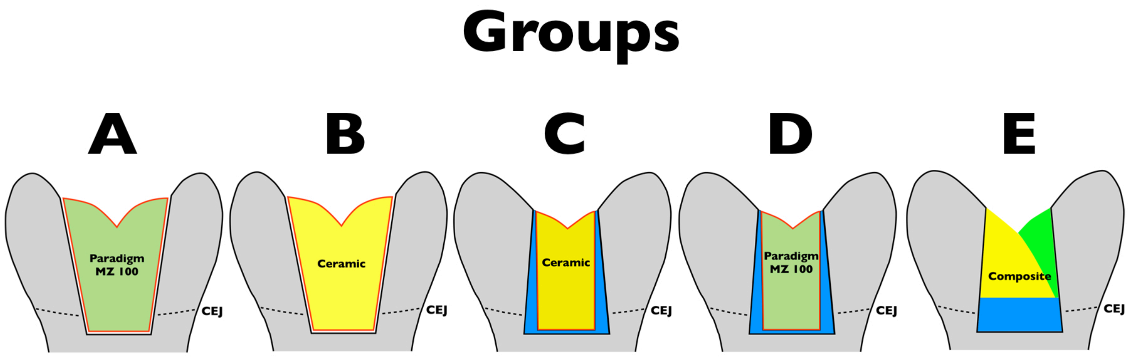
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B
C
D
E
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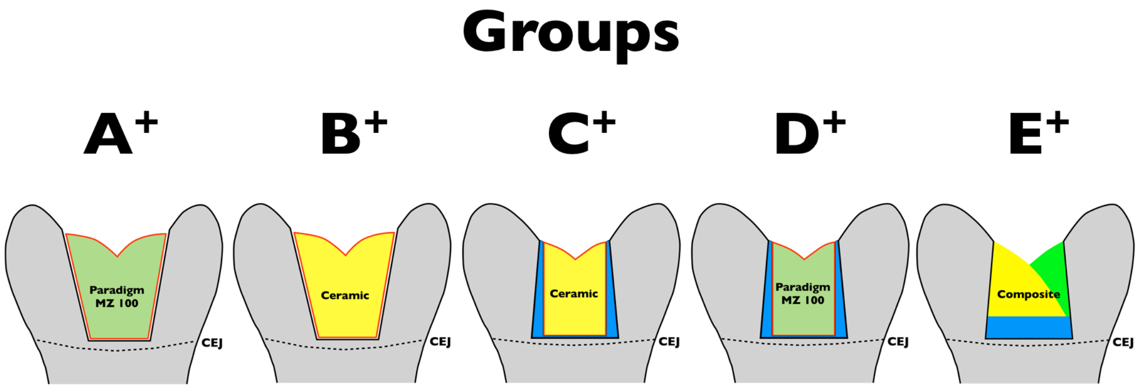
Ceramic
Ceramic
Paradigm MZ 100
Composite
CEJ

Fig.1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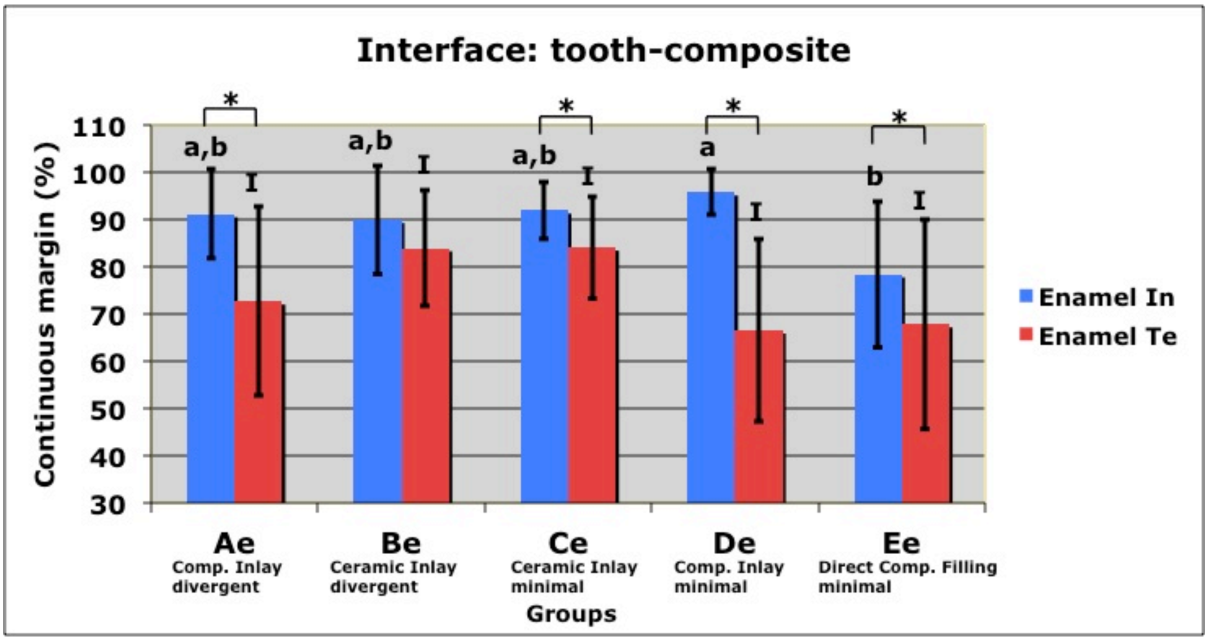
Ceramic
Paradigm MZ 100
Composite
CEJ

Fig.2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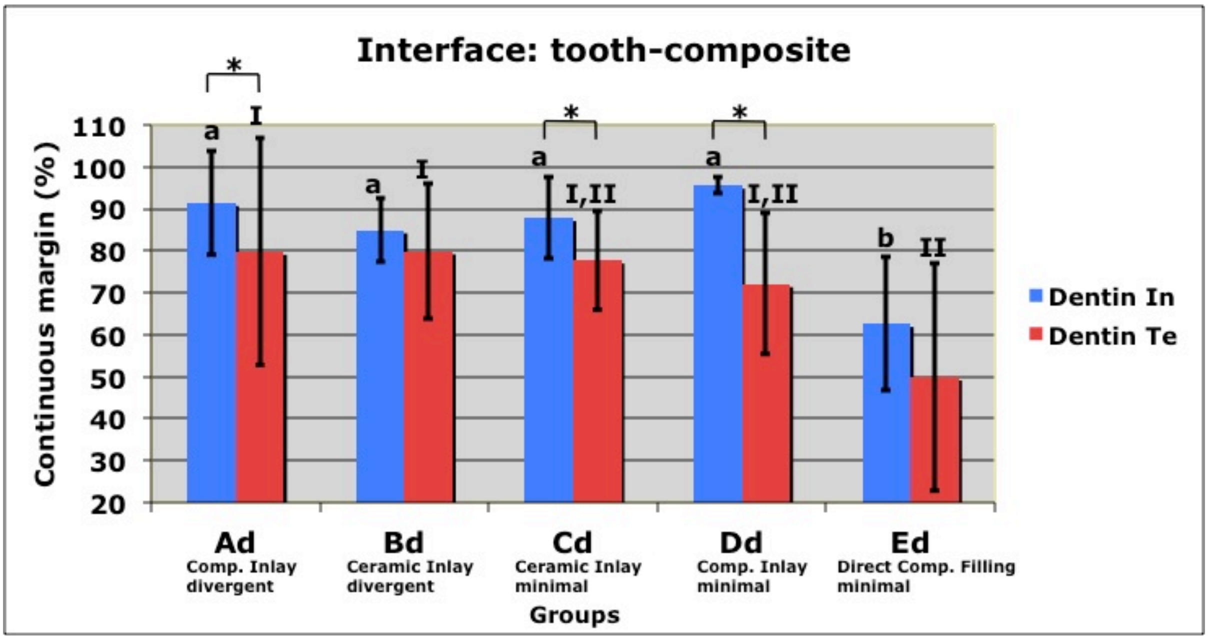
100
90
80
70
60
50
40
30
*
a,b
I
a,b
I
a,b
I
a
I
b
I
Ae
Comp. Inlay divergent
Be
Ceramic Inlay divergent
Ce
Ceramic Inlay minimal
De
Comp. Inlay minimal
Ee
Direct Comp. Filling minimal
Groups
Enamel In
Enamel Te

Fig.3


Interface: tooth-composite
Continuous margin (%)
110
100
90
80
70
60
50
40
30
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*
a
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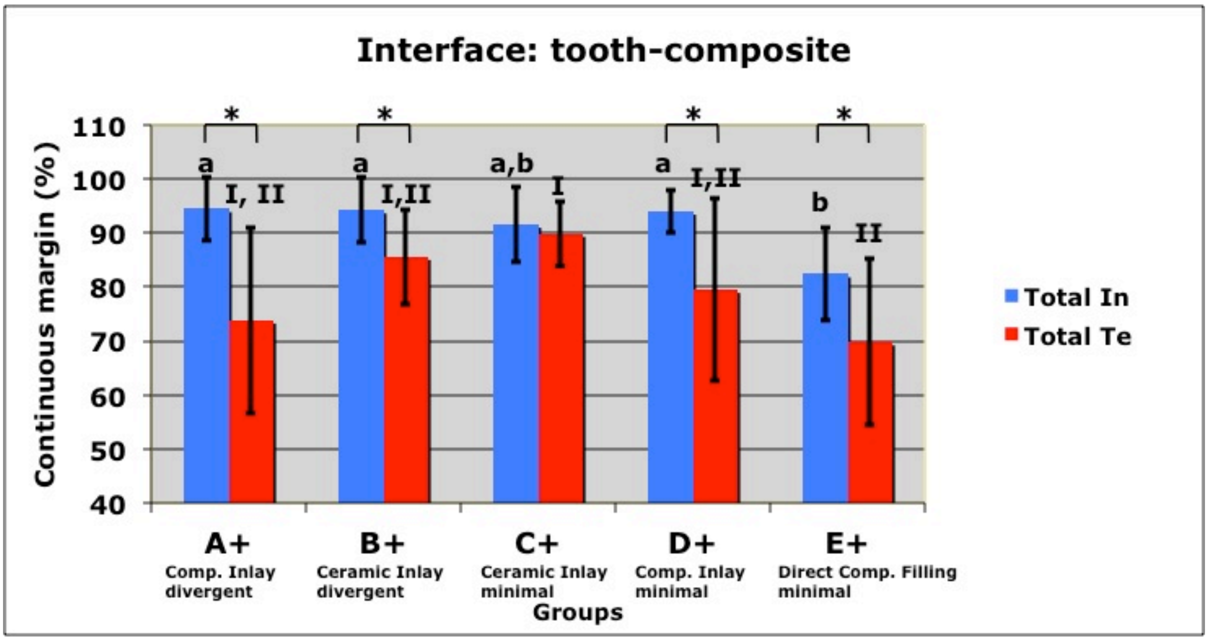
I,II
a
I,II
b
II
Ad
Comp. Inlay divergent
Bd
Ceramic Inlay divergent
Cd
Ceramic Inlay minimal
Dd
Comp. Inlay minimal
Ed
Direct Comp. Filling minimal
Groups
Dentin In
Dentin Te

Fig.4



Interface: tooth-composite
Continuous margin (%)
110
100
90
80
70
60
50
40
*
a
I, II
I,II
a,b
I
b
II
Total In
Total Te
A+
Comp. Inlay divergent
B+
Ceramic Inlay divergent
C+
Ceramic Inlay minimal
D+
Comp. Inlay minimal
E+
Direct Comp. Filling minimal
Groups

Fig.5

Legends

Fig. 1: Description of experimental groups A–E prepared also in dentin

Fig. 2: Description of experimental groups A^+–E^+ prepared only in enamel

Fig. 3: Continuous margins in enamel of the interface tooth-luting composite for groups prepared below the CEJ.

Percentages (mean ± SD) of continuous margins in experimental groups Ae–Ee as determined initially (In) and terminally (Te) TML in enamel. Subsets not significantly different are indicated by same superscript letters or numbers, respectively. Asterisks indicate significant differences between In and Te.

Fig. 4: Continuous margins in dentin of the interface tooth-luting composite for groups prepared below the CEJ.

Percentages (mean ± SD) of continuous margins in experimental groups Ad–Ed as determined initially (In) and terminally (Te) TML in dentin. Subsets not significantly different are indicated by same superscript letters or numbers, respectively. Asterisks indicate significant differences between In and Te.

Fig. 5: Continuous margins in enamel of the interface tooth-composite for groups prepared above CEJ.

Percentages (mean ± SD) of continuous margins in experimental groups A^+–E^+ as determined initially (In) and terminally (Te) TML in enamel. Subsets not significantly different are indicated by same superscript letters or numbers, respectively. Asterisks indicate significant differences between In and Te.